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TP8810E

EVALUATION OF MPB ICE THICKNESS MEASUREMENT SENSOR

Final Report

Prepared for
Transportation Development Centre
Transport Canada

by

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PROJECT TEAM

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Un sommaire en français de ce document est inclus avant la table des matières.

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17. Abstract

MPB Technologies Inc. developed a helicopter-borne sea ice thickness measurement sensor for the Transportation Development Centre. Canpolar evaluated the sensor in laboratory bench tests and in field tests in the Canadian Arctic.

The sensor included a novel synthetic pulse radar operating at 30, 60, 90, 120 and 150 MHZ. Although the radar met its functional specifications of a receiver noise figure of 6 dB in passbands of 5 MHZ and a transmit power of 100 W, it failed to operate in the Arctic.

Because of the level of effort required to rebuild the unit to be operational and the questionable superiority of this sensor over existing radar ice thickness sensors, further effort is not recommended.

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17. Résumé

MPB Technologies Inc. a mis au point, pour le compte du CDT, un dispositif de télémesure de l'épaisseur des glaces de mer à partir d'un hélicoptère. Canpolar a, pour sa part, évalué ce dispositif en laboratoire et in situ dans l'Arctique canadien.

Ce dispositif est basé sur un radar à impulsions synthétiques novateur, capable de fonctionner à 30, 60, 90, 120 et 150 MHz. Bien qu'il ait satisfait aux spécifications fonctionnelles imposant un rapport signal/bruit de récepteur de 6 db pour des bandes passantes de 5 MHz et une puissance d'émission de 100 W, ce radar n'a pas fonctionné dans l'Arctique.

Compte tenu, d'une part, de l'ampleur des travaux nécessaires pour remettre l'appareil en état de fonctionner et, d'autre part, de la supériorité toute hypothétique de ce dispositif par rapport à d'autres radars de télémesure de l'épaisseur des glaces existants, il est recommandé de ne pas pousser plus loin les travaux.

18. Mots-clés	19. Diffusion
Glaces de mer, radar, radar à impulsions synthétiques, radar à impulsions, épaisseur des glaces, télémesure.	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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SUMMARY

MPB Technologies Inc., Dorval, has developed a helicopter-borne sea ice thickness measurement sensor for Transport Canada. The motivation for this development is to provide an operational system for measurement of sea ice thickness from a helicopter, in real time, for Coast Guard Arctic operations. In 1985 Canpolar was contracted to evaluate the MPB device.

MPB worked on three different approaches to ice thickness measurement using VHF radio frequencies: (1) synthetic pulse radar (SPR), using frequencies of 30, 60, 90, 120 and 150 MHz; (2) amplitude modulated radar (AMR), using a relatively narrow band at 90 or 100 MHz; (3) video pulse radar (VPR), using a 5 ns pulse width impulse radar.

The initial prototypes of the SPR and AMR were tested in 1980 in the Arctic by MPB. Subsequently, a number of modifications were made and the VPR was tested in 1983 on Lake Melville. In 1985 Canpolar examined the VPR and noted that the SPR had been disassembled. This was reassembled for bench tests in March 1987.

For these bench tests the wideband transmitter of the VPR was used in conjunction with the five narrow passbands of the SPR receiver. The unit appeared to meet its functional specifications; however, a number of operational problems were encountered, including arcing, intermittent operation, and unsuitable connectors. In spite of these difficulties the unit was taken to the Arctic, but when it arrived it was no longer functional.

The antenna designed for the MPB sensor is a loaded dipole with shielding that can be quickly mounted and disconnected from a Bell 206B helicopter. Although some of the welds failed during shipment, this approach appears mechanically effective and easy to operate.

Because of the necessity to rebuild the MPB unit before any further testing could take place, and because it is not yet clear that the synthetic pulse radar is more effective in principle than existing radars, and because of the inherent limitations of radar sounding of sea ice, further development work is not recommended.

SOMMAIRE

MPB Technologies Inc. de Dorval, a mis au point, pour le compte de Transports Canada, un dispositif de télémesure de l'épaisseur des glaces de mer à partir des airs. L'idée derrière cette réalisation était de fournir à la Garde côtière canadienne un système opérationnel permettant la télémesure en temps réel de l'épaisseur des glaces de mer à partir d'un hélicoptère. En 1985, Canpolar a été chargé d'évaluer le prototype créé par MPB Technologies Inc.

Cette dernière avait exploré trois filières différentes exploitant les radio-fréquences VHF: 1) le radar à impulsions synthétiques (RIS), fonctionnant à 30, 60, 90, 120 et 150 MHz; 2) le radar à modulation d'amplitude (RMA), qui fonctionne dans une bande relativement étroite centrée sur 90 ou 100 MHz; et 3) le radar "video pulse" (RVP), une variante du radar à impulsions, dont la durée d'impulsion est de 5 ns.

Le premier prototype a été testé par MPB en 1980, dans l'Arctique, en version RIS et RMA; puis, ce prototype a été modifié pour en faire un système RVP, lequel a été essayé en 1983 au-dessus du Lac Melville. En 1985, Canpolar a examiné cette version, notant au passage que le RIS avait été désassemblé. Il a donc fallu le remonter en vue des essais en laboratoire de mars 1987.

Pour les besoins de ces essais, Canpolar a utilisé l'émetteur à large bande du RVP ainsi que les cinq bandes passantes étroites du récepteur RIS. L'ensemble semblait répondre aux spécifications formulées, mais à tout de même éprouvé un certain nombre de problèmes de fonctionnement: formation d'arcs, fonctionnement sporadique et connexions inappropriées. Malgré ces difficultés, l'ensemble a été transporté dans l'Arctique, où il n'a cependant jamais été possible de le faire fonctionner.

L'antenne conçue pour le dispositif de la MPB est un doublet à charge série résistive, qui se caractérise par une pose/dépose rapides sur hélicoptère Bell 206b. Bien que certaines soudures aient lâché en cours de transport, le montage adopté semblait offrir une bonne résistance mécanique et être d'exploitation aisée.

Compte tenu: 1) de la nécessité de reconstruire le dispositif MPB avant de pouvoir procéder à d'autres essais; 2) du fait que la supériorité du radar à impulsions synthétiques sur les autres radars est loin d'être clairement établie; et 3) des limites inhérentes de la technique radar dans l'application envisagée, il n'est pas recommandé de pousser plus loin les travaux.

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1. INTRODUCTION

Measurement of the thickness of the many types of floating ice, particularly for rapid surveys over large areas, poses an important problem in development of Canada's marine resources. The enormous range of ice types, in the various regions, over all seasons, places constraints on shipping, drilling, fishing and offshore construction. In addition, ice thickness is an important parameter in many scientific studies, such as ice and climate modelling [1*].

In August, 1985 Canpolar Inc. (formerly Canpolar Consultants Ltd.) was contracted by the Transportation Development Centre (TDC) to evaluate the Ice Thickness Measurement Sensor which had been under development for several years at MPB Technologies Inc., Dorval (MPB). Of particular interest was assessing the capability of Synthetic Pulse Radar (SPR) for helicopter-borne measurement of sea ice thickness [2,3,4].

Site visits and bench tests were made at MPB's facility in September, 1985; March, 1987; and April, 1987. The SPR system was taken to Resolute Bay, N.W.T. in April - May 1987.

This report documents the state of development of the system during Canpolar's involvement, and the results of our tests. Recommendations for future effort are also given.

* Numbers in square brackets designate references listed at the end of the report.

2. SYSTEM DESCRIPTION

Three different radar-based ice thickness sensor approaches were utilized by MPB:

1. Synthetic Pulse Radar (SPR) - a radar with a pulse made up of five relatively narrow Fourier components at frequencies of 30, 60, 50, 120 and 150 MHz;

2. Amplitude Modulated Radar (AMR) - a 90 or 200 MHz modulated pulse radar to complement the SPR (called "IMR" by MPB);

3. Video Pulse Radar (VPR) - a 5 ns impulse radar.

2.1. Synthetic Pulse Radar (SPR)

The initial design proposed by MPB was for a radar which generated an impulse synthetically using five harmonic frequencies of 30 MHz. An initial prototype was built and tested by 1980 [5,6,7]. This radar offers the ability, in principle, of avoiding problems of wide bandwidth signals, both in reducing spectral noise and increasing receiver sensitivity.

A second prototype was designed between 1980 and 1983 [8,9], but due to changes in personnel was never fully completed. In 1983 a field program was undertaken on Lake Melville but the SPR was not tested at that time. Instead, the SPR was partially disassembled and the VPR impulse radar was built and taken to the field.

After Canpolar's initial visit to MPB in September, 1985, the SPR was re-assembled and this radar was bench tested in March, 1987. Only the synthetic pulse receiver was re-built; the VPR wideband transmitter was used.

2.2 Amplitude Modulated Radar (AMR)

This radar (called "IMR" by MPB) was originally planned as a 100 MHz amplitude modulated pulse radar with a pulse length of 50 ns. It was planned as an adjunct to the SPR for use in ice thicker than 2 m -- for which the SPR would give ambiguous echoes. If such a radar had high peak power and a sensitive receiver it could be a good device for measuring the thickness of multi-year ice greater than 4 m thick.

The version seen by Canpolar merely modulates the 90 MHz SPR signal and detects it with a wideband receiver. Since the peak power and receiver sensitivity for this signal would be no greater than for the SPR, the advantage of implementing the AMR would merely be to reduce the ambiguity associated with the SPR when the ice thickness is greater than approximately 2 m.

2.3. Video Pulse Radar (VPR)

This impulse radar [5] and was examined by Canpolar, but not tested, in September 1985. Engineering comments on the electronic design are included in Appendix A along with MPB's response.

2.4 System Controller

MPB has designed and build a digital system controller [10] for the three radars described above. The controller is based on an Intel 8088 microprocessor for which the software is written in assembler. Comments on the software documentation are given in Appendix B.

2.5 Antenna

A helicopter-mounted antenna which would be used for any of the sensors [11] was designed and built [6]. The shielded, resistively-loaded dipole approach is similar to that used in commercially available impulse radar systems. The antenna system has been certified for mounting on a Bell 206B helicopter.

2.6 Display and Recording

The system does not have an easy means to display, record or playback the data. Display is via an oscilloscope and plans to use a digital data recorder were not fully implemented.

3. BENCH TEST OF SPR

In March 1987 Canpolar performed a test of the re-assembled SPR at MPB's facility. The objective was to determine whether the system met its functional specifications (given in Table 3). Test points (TP) refer to MPB documentation dated Jan 8, 1986.

3.1 Equipment Used

* MPB SPR Transmitter (Tx), Receiver (Rx) and ancillary equipment, such as control console, power supplies, display and recording devices, cables, etc.
* Oscilloscopes, Tektronix 485 and 7854 (485 used except as noted)
* Signal generator, Wavetek Model 2001
* Frequency counter, 200 MHz
* Spectrum analyzer, Hewlett Packard 8552A IF unit with 8554B RF plug-in and 141T display
* Polaroid camera with oscilloscope mount and film (usable also with spectrum analyzer)
* Assorted calibrated attenuators
* Standard RF cables, connectors, adapters, T-junctions, etc.

3.2 Transmitter Tests

3.2.1 Peak power and pulse width

The transmitter output was connected to the oscilloscope (50 ohm) input via a 20 dB attenuator, and the waveform observed and photographed; see Figure 1. The observed peak was 9.0 volts, which is 162 W in 50 ohms. The output pulse is quite clean and rectangular, and about 7 ns wide.

3.2.2 Spectrum

The transmitter output was connected to the spectrum analyzer through a 30 dB attenuator. The analyzer bandwidth was set to 300 kHz, and the display shown in Figure 2 was observed. The null at about 150 MHz is consistent with the observed pulse width.

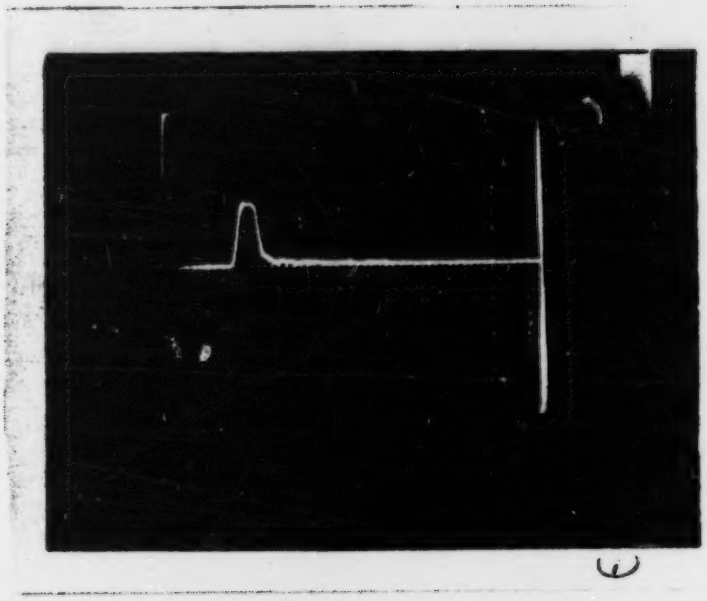

Figure 1. Transmitted pulse following 20 dB attenuation. 5 V/div vertical; 10 ns/div horizontal.

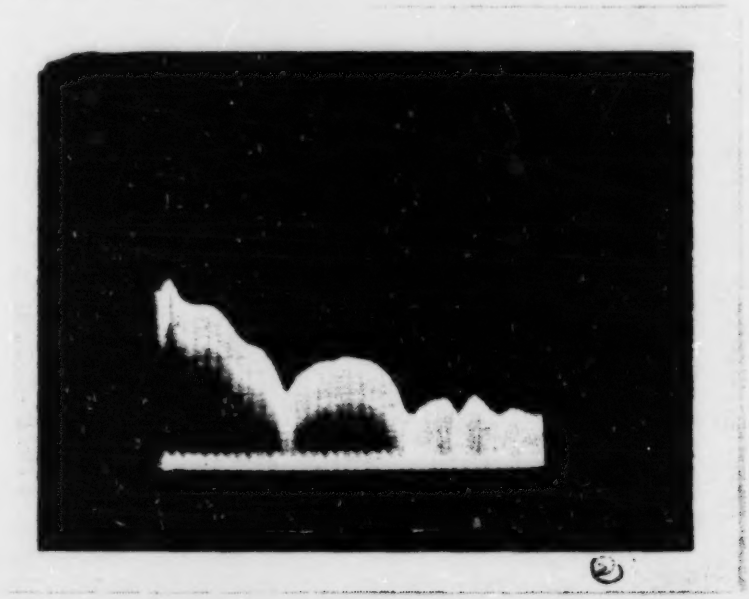

Figure 2. Spectrum of transmitted pulse following 30 dB attenuation. Reference level at top of image is 0 dBm; vertical scale is 10 dB/div; horizontal 50 MHz/div.

3.3 Receiver Tests

3.3.1 Receiver output spectrum with transmitter on

The equipment was connected as for the bandwidth measurements (below), except that the transmitter was connected to the receiver input through a 100 dB attenuator. The spectrum analyzer display of Figure 3 was obtained.

3.3.2 Bandwidth

The receiver input was then terminated in 50 ohms, and its output (TP2) was connected to the spectrum analyzer. All receiver gains (i.e. at all five frequencies) were set to maximum, and the analyzer bandwidth was set at 300 kHz. The display shown in Figure 4 was observed. By expanding the display around each of the five passbands, the displays shown in Figures 5 to 9 were obtained. Since the receiver input noise can be assumed to be flat over tens of megahertz, the width of each passband is about 5 MHz.

3.3.3 Spurious frequencies

The recorded spectra show anomalous peaks at various frequencies. The broad anomaly shown in Figure 5 on the left skirt of the 30 MHz passband was found to rise and fall in amplitude as the receiver gain at that frequency was increased or decreased, hence appeared to be due to some source of interference entering the receiver prior to the attenuators.

The other peaks seemed to be independent of receiver gains, and therefore apparently due to stray signals picked up following the attenuators in the receiver. They were apparently not artifacts of the analyzer itself, since they disappeared when the receiver was disconnected from the analyzer. While none of these spurious signals was expected to degrade the system performance seriously, two of them (60 MHz and 120 MHz) are centred on receiver passbands.

3.3.4 Noise Figure

An attempt was made to measure the noise figure (NF) at each of the five frequencies using the available equipment (a radio frequency millivoltmeter and a calibrated noise source would have been very useful, but these items were not obtainable). At each frequency, the corresponding gain was set at maximum and the others at minimum. The signal generator was connected to the receiver input through a 40 dB attenuator, and the oscilloscope was connected to TP2. The signal generator was first tuned to the centre of the passband, then set for minimum obtainable output. The noise level was noted on the display, then the generator level was increased until the receiver output level was approximately 3 dB greater than before.

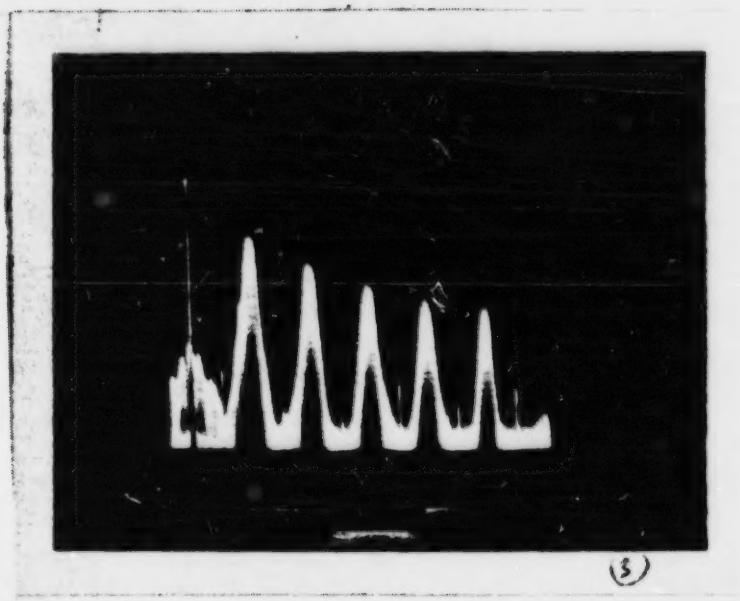

Figure 3. Spectrum of Rx output with Tx driving Rx through 100 dB attenuator. Vertical 10 dBm/div; horizontal 20 MHz/div.

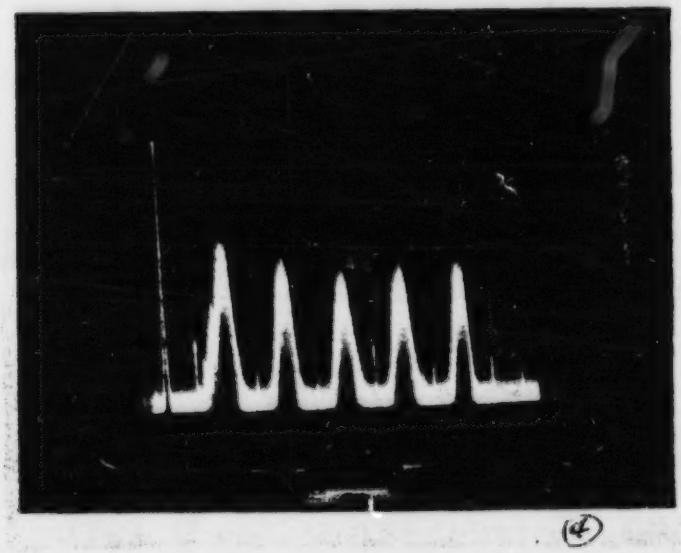

Figure 4. Spectrum of Rx output noise only (Tx not connected). Vertical 10 dBm/div; horizontal 20 MHz/div.

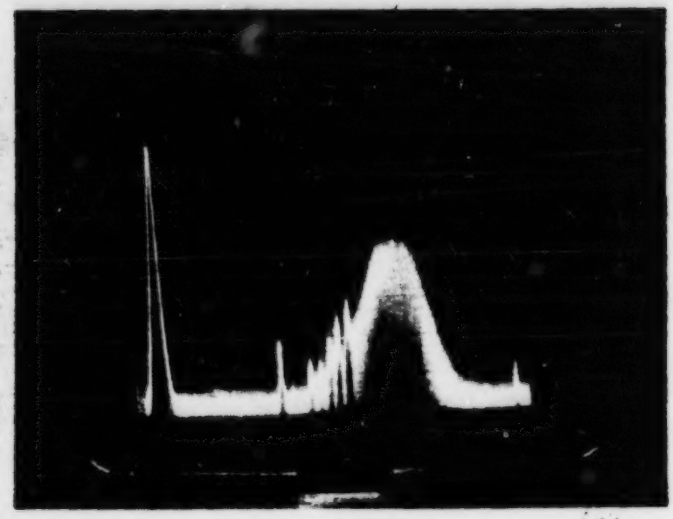

Figure 5. 30 MHz passband (noise only, no Tx). Vertical 10 dBm/div; horizontal 5 MHz/div.

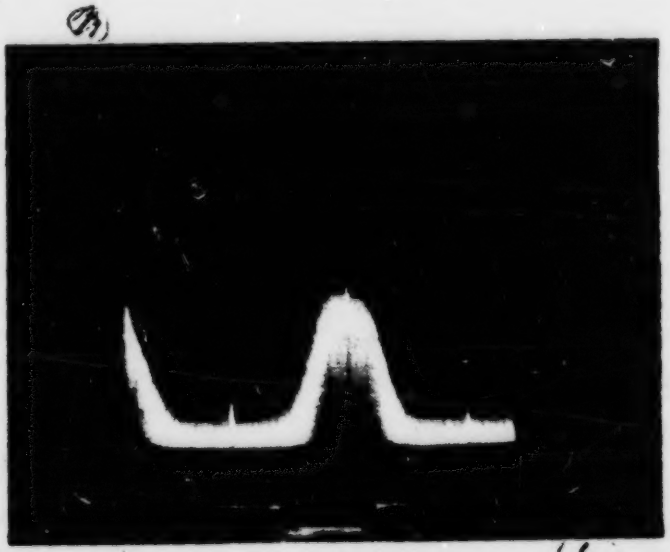

Figure 6. 60 MHz passband (noise only, no Tx). Vertical 10 dBm/div; horizontal 5 MHz/div.

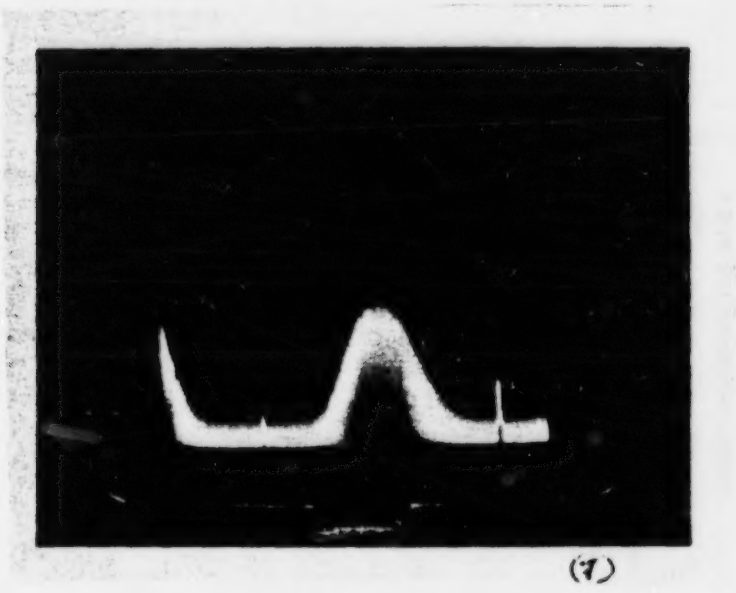

Figure 7. 90 MHz passband (noise only, no Tx). Vertical 10 dBm/div, horizontal 5 MHz/div.

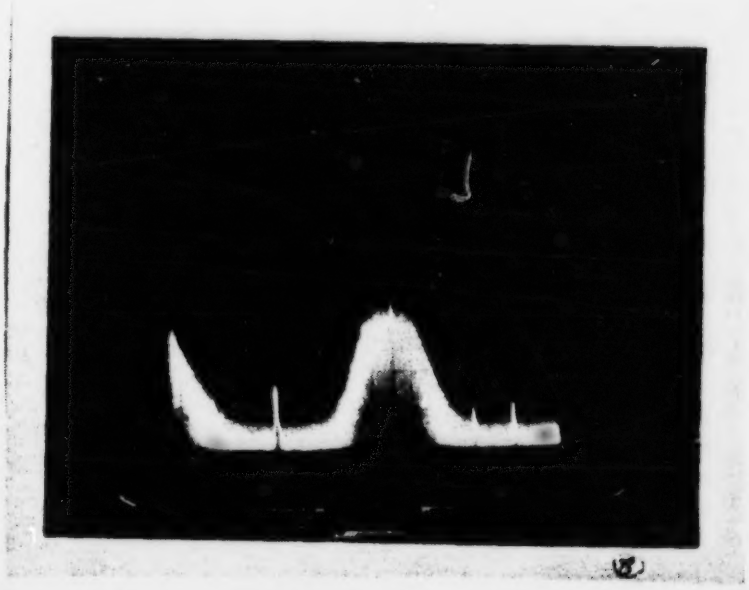

Figure 8. 120 MHz passband (noise only, no Tx). Vertical 10 dBm/div, horizontal 5 MHz/div.

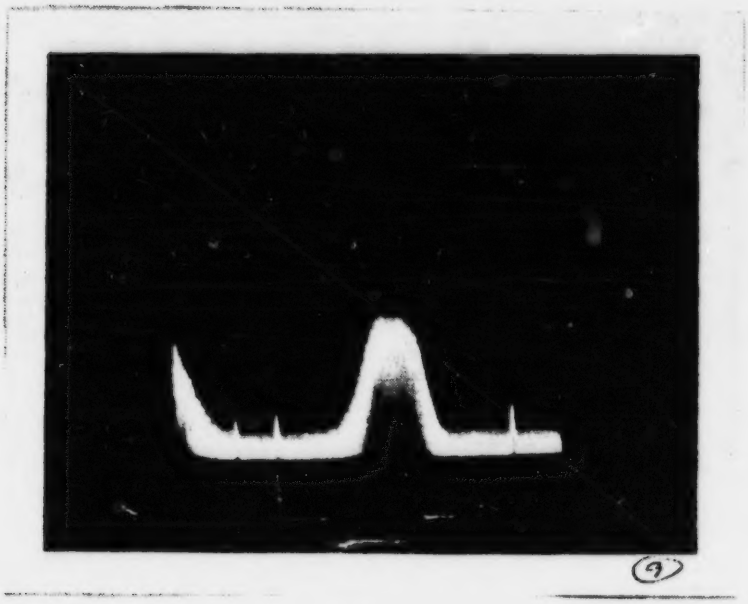

Figure 9. 150 MHz passband (noise only, no Tx). Vertical 10 dBm/div, horizontal 5 MHz/div.

The generator level was recorded, and noise figure calculated from

$$NF = P_{1:1} - 30 - 10 \log (kTf) \qquad (1)$$
$$= P_{1:1} + 106.8$$

where $P_{1:1}$ = Signal generator power obtained above, in dBm

f = Noise bandwidth, 5 MHz.

Because of the subjective nature of the oscilloscope observations, two measurements were made by different observers at each frequency. The results are given in Table 1.

Table 1. Noise figure measurements

Frequency MHz	Generator Level dBm	Noise Figure dB
30	-101	5.8
60	-98.5	8.3
90	-91	15.8
120	-100.5	6.3
150	-101	5.8

The measured noise figure at 90 MHz was very high, but the high reading is believed to be due to leakage from other passbands which effectively increased the noise bandwidth. Other harmonics were in fact observed when the measurement was made. The 90 MHz channel was also observed to have an intermittent fault, possibly a loose connection, which caused its output level to fall sharply; if this occurred during the noise measurement, it would have aggravated leakage from other channels.

The measurements at 60 MHz and 120 MHz were more reasonable, but still greater than 6 dB. These results may be associated with the presence of anomalous spectral peaks as noted earlier at or near the centres of these passbands (see Figures 6 and 8). The other three passbands do not contain these peaks.

The measurements at 30 MHz and 150 MHz are less than 6 dB. It should be noted that measurement error may have been as great as 2 - 3 dB, so these two measurements are not inconsistent with a true NF less than 3 dB. It should also be noted that the true NF can be assumed to be fairly constant, or at least smoothly varying, from 30 MHz to 150 MHz; sudden variations like that observed at 90 MHz are therefore almost certainly due to measurement error.

In conclusion, the test results cannot be said to prove that NF was less than 6 dB, but they also don't prove that it was greater. Since the amplifiers that determine NF were purchased as standard (presumably well tested) items from a reputable manufacturer, it seems likely that the true NF is closer to the manufacturer's specification (2 dB typical) than to the results of our measurements.

3.3.5 Phase and amplitude adjustments

To check amplitude adjustability, the transmitter was connected to the receiver through a 100 dB attenuator and the receiver output was observed using the Tektronix 7854 oscilloscope as the gain of each channel was adjusted from minimum to maximum, with the other channels set for minimum gain. The results are shown in Table 2.

Table 2. Amplitude adjustment ranges

Frequency MHz	Min output mV	Max output mV	Adj. range dB
30	--	--	--
60	30	110	11.3
90	30	110	11.3
120	30	90	9.5
150	30	44	3.3

Phase adjustability was confirmed by observing the output of one receiver channel on the oscilloscope, relative to the 30 MHz output, with the transmitter connected to the receiver as for the amplitude tests. The range at 60 MHz was approximately 150 degrees.

3.3.6 Dynamic range

The spectrum analyzer was connected to the receiver output, and the transmitter was connected to the receiver via an attenuation of approximately 100 dB. Using the spectrum analyzer display to indicate saturation, the dynamic range of the receiver (ratio of maximum input without saturation to minimum detectable input) was found to be about 20 dB.

3.4 Physical dimensions

The main console is 52 cm wide, 50 cm high, and 40 cm deep. The carrying handles, when in use, increase the width by about 4 cm. an allowance of about 2 cm should be made for front panel connectors and controls.

The control box is 22 cm wide, 12 cm high, and 8 cm deep.

3.5 Summary

The measurement results are summarized in Table 3, with the specified values included for reference.

Table 3. Summary of specified and measured results

	Specified	Measured
Transmitter		
Peak power, W	>100	162
Receiver		
Passband centres, MHz	30,60,90,120,150	30,60,90,120,150
Bandwidth per passband, MHz	5	5
Phase/Gain adj. on each passband	Yes	Yes
Noise figure, dB	<6	<6[1]
Dynamic range, dB	--	20 dB
Physical dimensions, cm		
Main console	--	52W X 50H X 40D[2]
Control box	--	22W X 12H X 8D

Notes:

1. The measurements are inconclusive, but in our judgment the specification was met.

2. The carrying handles, when in use, increase the width by about 4 cm, and an allowance of about 2 cm should be made for front panel connectors and controls.

---

4. FIELD TESTS OF SPR

Since the SPR passed its bench test, it was decided to try to evaluate it in the Arctic. Due to delays in the re-assembly of the SPR by MPB, there was no time to thoroughly debug the system before the field program started in April 1987 [12]. Notes of the problems and observations made are given here.

4.1 Tests at Montreal

4.1.1. Electronics unit

- when the front panel was tightened down the system would not work
- when tightening or applying pressure to the front panels of the modules, arcing could be heard and seen from the rear edge connectors
- the sampling unit was not fully functional (known)
- no proper cabling for antenna Rx and Tx connections; makeshift cables were made for this by putting together assorted BNC cables and BNC to SMA adapters

4.1.2. Antenna

- few bends in frame
- missing one quick-release pin used to hold antenna to helicopter

4.2 Tests at Toronto

4.2.1. Electronics Unit

- Many front panel screws had worked loose, although tightened down before shipping
- DIP connectors for flat wire cables between modules had worked loose

4.2.2. Antenna

- two non-structural welds loose

4.2.3. Operational problems

- loose connections in the edge connectors, still did not work when tightened down; arcing when adjusted with power on

- DIP connector for the hand-held controller not secure, came loose with movement of hand-held controller, causing erratic operation

4.3 Tests at Resolute

4.3.1 Electronics unit

- front panel screws worked loose again
- DIP connectors separated or loose

4.3.2 Antenna

- coax cable from BNC jack to Tx antenna broken
- other quick release pin broken
- welds broken at one end of dividing frame between Rx and Tx antennas

4.3.3 Operational problems

- sync pulse for transmitter was intermittent
- hand-held controller display changed with movement of its cable
- hand-held controller switched on and off when pressure applied to sync unit
- hand-held controller would not operate the unit properly without a lot of fiddling with cables, and would stop operating correctly with the slightest touch
- the edge connectors at the back of the interface modules and sync unit were loose and out of alignment. This problem was first noted in Montreal when the Rx-Tx unit would not function properly when the sync unit was tightened down. The entire card cage with the edge connectors needs to be rebuilt for operations in the high vibration environment of a helicopter.
- the flat wire cables connecting the interface modules and the sync unit together are attached to the circuit boards with DIP connectors. The connections have become worn with use and no longer hold tightly to the sockets. Some connectors disconnected themselves during shipping and most have loose connections that fail intermittently.

4.4 RF Shielding

Many Arctic operations use HF radio for communications. The MPB unit emitted such enormous RF noise that it made HF communications impossible. Presumably this noise was from the computer controller. Much better shielding is required for Arctic work.

4.5 Antenna and Mount

The antenna was deployed under a Bell 206B helicopter to confirm its mechanical effectiveness. It fitted well and was mounted easily by replacing the cargo hook and its mount. The antenna was then rigidly attached to the aircraft. The pilot would not fly with the antenna mounted because of the broken welds and pins noted above.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Although the MPB ice thickness measurement sensor was able to be demonstrated in the laboratory, it is not currently functional. It has evolved over a number of years and the documentation had not kept up with the implementation. Through all of this period the synthetic pulse radar option has not been adequately tested under flying conditions. The tests of the first prototype [7] indicated problems with ambiguity between top and bottom echoes from the ice; high flying height giving a large footprint; and a need to calibrate the synthetic pulse.

The amplitude modulated radar and the impulse radar, which formed part of the sensor at various times in its evolution, do not appear to offer anything that is not available from commercial suppliers. These units were not tested by Canpolar.

The antenna design does appear to be practical for helicopter use. Although Canpolar did not test the antenna electrically, the results from MPB's tests are well documented [11].

The implementation of the system was not adequate for helicopter use. The types of connectors used were not robust enough for the high vibration encountered in the field. Moreover the computer controller would not have been easy to use and the lack of adequate display would have made operations difficult.

It appears that the synthetic pulse radar approach, although interesting, may not in fact offer substantially more than wideband impulse radars which have been available for over fifteen years. A discussion of some aspects relevant to this issue is given in Appendix D. Work along similar lines is being carried out at the University of Toronto [13] using a system which steps through a number of frequencies sequentially. This approach, however, is not fast enough for airborne operations.

5.2 Recommendations

It is clear from the results of this study that in order to further this specific development, extensive rebuilding of the present system will be required. Given that there are already relatively practical airborne microwave sensors for ice thickness measurement, and that there are strong limitations to the use of any radar sensor for measurement of ice thickness, and given the questions about the synthetic pulse approach in principle, we do not recommend further development at this time.

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APPENDIX A

Engineering comments on the Video Pulse Radar and reply by MPB, September-November 1985

Micro Systems Engineering
43 Nantucket Blvd., Scarborough, Ontario M1P 2N5. (416) 759-4055

RECEIVED
SEP 25 1985

September 23, 1985

Dr. James Rossiter
Canpolar Consultants Ltd.
421 Eglinton Ave. West
Suite 4
Toronto, Ontario M5N 1A4

Dear Jamie,

Attached is a revised version of my notes on the MPB electronics for the ice thickness radar. Some of my questions are still unanswered, due to a lack of time during the Montreal visit. I think the important things have been pretty well covered, however.

Also attached is an interim invoice.

Sincerely.

Eric Vannerson

Eric Vannerson, P.Eng.

Notes on the Electronic Design for the MPB Ice-Thickness Radar
September 23, 1985

SEP 25 1985

Signal format:

In the introduction (1.1), neither the form of the signal nor the sampling scheme is clear. Evidently the pulse repitition rate is 4 microseconds, not nanoseconds as stated. In 1.3(ii), it is stated that 256 triggers are required to obtain a complete waveform. Should this be 512? What are the units of trigger delay (0 to 59 what)?

Fast ramp generation:

The change in the forward drop of CR3 with temperature results in a drift in the starting point of the fast ramp. The ramp linearity is degraded by C39 and R38.

Slow ramp generation:

The D/A circuit is not very precise. In addition to drifts associated with resistors and capacitors, there is a pulse-to-pulse error associated with the differential nonlinearity of the D/A. The actual size of a particular step in delay, could easily vary +/- 50% from 1 ns. The error statistics are not easy to figure out, but the worst errors occur as the major bits into the D/A change state. As I examined the circuit initially, it crossed my mind that it might be simpler to generate the two ramps using a pair of identical current sources (PNP transistors) driving two capacitances in the ratio of the desired ramp slopes. Having seen the noise problems in the existing circuit and realized the fundamental defect described above, I see this as even more appealing.

What does R21 on the Scanning Unit do?

Sample pulse generation:

The RC lowpass on the slow ramp signal adds a long delay (approx 70 us) which must be taken into account somehow, and degrades the linearity of the ramp. 6.2 implies that the purpose of U14 is to produce a pulse with a faster rise time than the output of U15; is the rise time of U14's output really significantly faster?

Scanning Unit - Sampler Interface:

Something is wrong in the documentation, apparently. The output of U14 will not drive the sampler as shown, since U14's output is always below ground. Also, there is no pull-down to the negative supply. Rene

observed the sampler drive pulse while we were there, and announced that it went up to about +5V. Obviously the circuit works, however it's actually wired.

Sampling circuit:

CR1 is said to prevent saturation of Q1; how could it do that? The circuitry for generating the sampling pulse seems awfully complex. Does CR3 really have the desired effect (ringing suppression)? R9 is probably supposed to be 120 ohms like R8. The hold capacitor C9 was specified as 8.2 pF to ensure adequate signal acquisition within 1 ns, Rene says. The acquisition time constant is about 30 ohms times (8.2+5)*1e-12, or .4 ns, so this is understandable.

R25 contributes a bit to the poor hold performance, since the hold time constant is only about 13*1E-12*1E7, or 130 microseconds, but does not by itself explain the observed performance. The observed drift (droop) rate was on the order of 1 volt in 4 microseconds at the output of the module, or about 1.6E4 V/sec at the hold capacitor. This implies a leakage current of about .2 microamperes. It is conceivable that the FET and PIN diodes have this much leakage.

The circuit as shown has another problem (observed after the Sep 20 visit to MPB). There is no resistor at the noninverting input of U1 to provide a path for bias current. Probably this is an error in the drawing, since it is difficult to imagine that the circuit would work at all without this resistor.

Power regulator on Scanning Unit:

The +15 and -15 supplies are adjustable, but the nominal voltage is not necessarily within the adjustment range. Would it not have been preferable to use an adjustable regulator, e.g. LM317, or settle for a fixed output? The same can be said for the +5 and -5.2 regulators.

Why supply the +5 and -5.2 regulators from +/-15V, rather than from +/-20, with bigger heat sinks if necessary? This should avoid some contamination of supplies which must be kept clean.

Transmitter:

It is not clear exactly how the storage line is connected; are the two avalanche transistors and associated independent, with their own storage lines, up to the point where their outputs are summed? Is the far end of each line open? What is the pulse shape, exactly? Must Q3 and Q4 be selected and/or matched?

T/R switch:

The circuit around U6 seems unnecessarily complex; is it really desirable to use an op amp here? Why not a comparator? The description of operation (4.2) says that the purpose of the voltage step-up and step-down is to "increase the limiting capabilities." What does this mean?

The polarity of the JFET's is incompatible with the polarity of zener diode CR5. In the circuit as drawn, the JFET gates are overdriven in the on state, and there is insufficient drive to turn them off.

Rene says that if the RF signal is very large, the switch output on entering the receive mode has a large negative tail, i.e. it starts negative and decays exponentially. I don't see an obvious explanation for this effect.

SPR:

Section 3.3 says that signal M1 originates in the Sync Unit. The schematic for the latter shows M1 as an input. 3.3 says the variable attenuators and phase shifters (in the receive path?) are controlled at the transmitter front panel; this seems strange.

Data latch:

Data latch U16 in the Sync Unit doesn't really seem to belong there. Shouldn't it be with the A/D (I guess the DMA module is a standard item)?

Power consumption:

Rene says the total power consumption of the system is 10-20 amps at 28V, or 280-560 watts. This certainly seems high.

Operation:

It would be nice if the operator could enter delay times in familiar units, and have the microprocessor translate into the programmable counter value.

It seems awkward for the operator to enter phase angles 0-360 degrees as numbers from 0 to 255. Does this have to be like this?

Wouldn't it be desirable to be able to store several sets of signal parameters in nonvolatile memory, and select one when necessary?

Documentation:

Errors in system description 1.1.

IC's use ref designation "A" on schematic, "U' in text.

The block diagram seems to work well as an index to module schematics. The individual schematics are well drawn and very readable.

It would be nice to have an overall timing diagram.

On the block diagram, the "Buffer" block presumably refers to U14 of the Scanning Unit.

On the Sync Unit schematic, slow ramp counter outputs are not marked. Also, it would be nice to have the remaining pin numbers on the D/A. The signal marked "TRIG" should probably be marked "TRIG-" instead.

On the Scanning Unit schematic, no values are given for R29 and R30. I assume U8 and U9 are either LF156A or LF156H, rather than LF1564 as marked.

On the Sample Unit schematic, label inside dotted box says "NAND SECOND PULSE." Presumably, the circuitry inside generates a "nanosecond pulse." CR1 should be drawn as a Schottky diode. T1 is shown being driven from the centre-tap of its primary, with both ends of the primary grounded. Rene says one end of the primary is actually open, but the secondary has a centre tap which is grounded.

On the Transmitter Module schematic, CR4 is shown backwards. The schematic says the storage line is 55m long; the text says .55m, which is presumably correct. R2 is marked 4.7n.

On the Receiver & T-R Switch schematic, "Weinschall" should be "Weinschel". R5 is marked "47n".

The Oscillator & Trigger Interface schematic shows the delay line sections in ns, rather than ns.

5.2 says the D/A U12 produces a ramp from 0 to 5.12V; actually, the output of U12 is a current, and the voltage swing is from 0 to about -2 volts.

In the middle of p. 12, paragraph 5.2, the sentence which begins "Delay times can be adjusted..." is garbled.

In 6.2, the sentence beginning "The current output of the D/A..." has a few words missing.

The source of the clock for the slow ramp counter is not clear from the drawings, although the answer is in the text.

There isn't much information on the SPR receiver.

E. Vanneman

MPB TECHNOLOGIES INC.
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(514) 683-1490 Telex 05-823509

November 16, 1985

RECEIVED
NOV 19 1985

MPB

Dr. J. Rossiter
CANPOLAR CONSULTANTS LTD.
421 Eglinton Avenue West
Suite 4,
Toronto, Ontario
M5N 1A4

Dear Dr. Rossiter:

Enclosed is the answer to the notes that you sent us. The estimate for implementing the synthetic radar for a bench test is approximately $12,500. That includes 5 man-weeks of Category 4 and 2 man-weeks for Category 2, plus miscellaneous materials.

Please call if you need further information.

Yours sincerely,

Dr. S.Y.K. Tam
Director
Electromagnetic Science
& Technology.

Enc.
/ec

RESPONSE TO CANPOLAR's NOTES OF SEPTEMBER 23, 1985, ON ELECTRONIC DESIGN FOR MPBT's ICE THICKNESS SENSOR

by: Andrej Puc and Rene Bourbonnais - November 8, 1985

1. Output Power

The output power of the VPR transmitter is defined as the peak power of the video pulse at the antenna input connector. At the present time this power is 140W measured on the 50 ohm load.

2. Sensitivity

The sensitivity of the VPR receiver is -90 dBm for a 6 dB S/N ratio. In averaging-mode, return signals with levels as low as -96 dBm can be observed.

3. Dynamic Range

The present dynamic range is limited by the sensitivity and the saturation of the receiver amplifier chain. This dynamic range is 30 dB for the present configuration.

Sea-Ice Radar - Answers to E. Vannerson's Comments

Signal Format

In order to acquire and digitize the received signal the sequential sampling method is used, similar to methods that are used in sampling oscilloscopes, and some digital oscilloscopes. The advantage of this method is that high frequency waveforms up to 1 GHz can be digitized, and that the effective receiver noise bandwidth can be reduced to several hundred kHz although the actual video pulse bandwidth is over 180 MHz. Therefore, the sensitivity of such a receiver is significantly larger with respect to a receiver that would measure return signals with a real time method.

The repetition rate of the sequential samples is 250 kHz, and is synchronized with the train of the transmitted pulses. Therefore, the radar pulses are transmitted and received (after a corresponding delay) every 4 microseconds. One measuring window contains 512 such pulses which are sampled sequentially with 1 nanosecond relative delays. Therefore, waveforms that are long 512 nanoseconds or less can be acquired within one window. However, it takes 512 x 4 μs

i.e.; 2048 μs to reconstruct a 512 nanoseconds (real time) long window.

The units of the trigger delay are $\frac{1}{15\ \text{MHz}} = 66.67$ ns

In other words one can vary the position of the 512 ns long receiving window within the range of 4 μs on the real time scale.

Fast Ramp Generation

It is true that the starting point of the fast ramp is temperature-dependent (approx. 0.05 ns/°C). But this does not affect the relative delay between the sequential samples (J12 in the measuring window), and therefore does not spoil the accuracy of measurements.

The purpose of R38 and C39 is to filter out a high frequency noise which might,otherwise, get superimposed on the fast ramp. Linearity of the fast ramp would be affected if the capacitor C39 would get discharged for a certain amount within the ramp period.

This discharge can be calculated as follows:

$$\Delta V_c = V_o\left(\frac{4.7 + 2.7}{4.7 + 2.7 + 0.1} - \frac{4.7}{4.7 + 0.1}\right)\left[1 - \exp\left(-4.10^{-6}/4.7\ 10^{3}\ 0.1\ 10^{-6}\right)\right]$$

$$= 0.000064\ V_o$$

Therefore the nonlinear distortion due to the R38 and C39 is less than 0.0064%, which is negligible by any sense.

Slow Ramp Generation

The D/A circuit is implemented by the Motorola IC, the relative accuracy of which is specified to be ± 0.05% error (maximum). Since only the relative accuracy counts in our case, the D/A circuit is very precise, i.e. at least 10 times more precise than a current generator with a PNP transistor suggested by Canpolar, not to mention the temperature stability. The quantization steps of the output, again, do not affect the relative accuracy but might contribute to a steady state error which does not degrade the accuracy of the ice thickness measurement.

However, if the digital input into the D/A converter was erroneous, then of course severe errors can occur. From error statistics point of view, the highest error bit rate of the binary signal into the D/A converter is not expected to be greater than 10^{-6} bit/sec which, again, is totally negligible.

We cannot figure out why the resistors and capacitances in our circuitry should cause more drift than those associated with transistor current generators. In any case, they are just passive components and can contribute only to a slow temperature drift. This temperature drift cannot cause significant timing error either within a measuring window which lasts only 2 ms or within a period of time needed for an averaging mode operation, i.e. approx. 25 ms.

Many other solutions are possible, of course, to obtain a desired ramp, but with respect to a linearity, temperature and leakage drifts we have found this method of D/A conversion superior to any analog solution, which would require more expensive components and quite complicated drift compensation circuits. Just a bipolar transistor and a capacitor would not be enough, because they would certainly be as sensitive, or even more, to noise problems as it is the digital ramp generator.

Finally, R21 really does not make much sense, but does not do any harm either.

Sample pulse generation

The purpose of an RC low-pass filter on the slow ramp is to suppress the high frequency switching and EMI noise on the ramp.

Its assimptotic delay is 80 μs (=RC). However, the effective measurements start after approx. 180 μs from the beginning of the slow ramp (controlled by the duration of the T/R switch off time). After this time the deviation of the ramp (RC output) from the normal straight line can be expressed as:

$$2\,\Delta U_\varepsilon/U_o = (2RC/2048\mu s)\left[\exp(-180\mu s/RC) - \exp(-2048\mu s/RC)\right]$$

$$\approx (160/2048)\exp(-180/80) = 0.0082$$

or less than 1%. Therefore, the time scale in the effective measuring window (from 180 μs to 2048 μs) is distorted less than 1% all over the range. In practice, the return signal occurs in time typically within less than 1/10 of the effective measuring window. Thus the measuring error due to the time scale distortion is always less than 0.1%, typically.

The IC U14 is just a TTL to ECL translator in order to drive the 50Ω line and, therefore, it yields faster rise time than a TTL output would.

Scanning Unit - Sampler Interface

There is a mistake in the drawing; the 50Ω pull up resistor and 0.1 μF AC coupling capacitor are missing at the output of the U14.

Sampling Circuit

The purpose of CR1 is basically to isolate the biasing of Q1 from the incoming line. At the same time the diode acts as the threshold detector. Namely, typical forward bias threshold of the CR1 (Schottky barrier diode) is 400 mV. This threshold also prevents the input pulse

(typically 800 mV) to saturate the Q1.

CR3 does suppress the oscillating tail of the pulse, generated by the step recovery diode CR2 simply because it acts as a threshold polarity switch.

R25 defines the gate bias of the S/H amplifier, higher value than 10 megaohm would not significantly improve the hold characteristic because of the sampling bridge leakage. Our measured equivalent RC constant, during the hold time (4 μs) is $\geq$ 60 μs which corresponds to

$$\Delta U_H \leq U_S(1 - \ell^{-\frac{4}{60}}) = 0.065\ U_S.$$

In other words, the voltage drop during the hold time is less than 6.5% by the sampled value.

The voltage drop of 1V would correspond to almost 20% of the sampled value (for the largest signal) and much more for the low level signals. We cannot figure out how this value was measured, since it does not even come close to our observations. It is possible that Canpolar observed some negative switching spikes that might occur if the sampling bridge and the S/H amplifier were not balanced (trimpots R10 and R18).

Finally, the voltage drop between the samples does not affect the accuracy of measurement in terms of distortion, since the average value of our acquired samples is what counts and this is proportional to original signal disregarding the voltage drop during the hold period. But, it does reduce the sensitivity of the sampler. For example: a 6% voltage drop reduces the sensitivity by 0.5 dB and a 20% voltage

drop reduces the sensitivity by 1.9 dB. Again, this does not affect the measurements over all since the sampled signal is well above the noise level.

There is a 2.7KΩ resistor missing at the noninverting input of the U_1 on the drawings.

Power Regulator on Scanning Unit

The present structure seems to us perfectly adequate and we do not see any need to introduce changes.

Transmitter

The unit turned out to be very reliable and effective. The shape of the output pulse is partially adjustable with the trimpot R18 and it also depends on the length of the storage line.

To our knowledge, there is no better unit available on the market at the present time.

T/R Switch

The switch was originally designed as a voltage control attenuator with as fast a response as 40 MHz. Few components were added for the particular application, presently used in the Sea Ice receiver.

A voltage comparator instead of the video amplifier as the line receiver, would simplify the circuit by removing two resistors and two capacitors, as suggested by Canpolar. This will reduce the cost of components by approx. $1.5 ! On the other hand, the unit would lose the capability of a continuous voltage control switching.

The polarity of the Zener diode CR5 should be switched around on the drawings.

Large negative tail appears when the signal is so big that it saturates the receiver amplifiers.

Data Latch:

Data Latch, although associated with A/D which is an analog module was placed in digital module for the following reasons:

1) The switching of digital gates causes transient noise on the power supply and ground lines. To minimize the sources of such disturbances around the analog circuitry, the latch was placed on the digital board.
2) There is no reason why it has to be close to the A/D since the information transmitted is digital.

SPR:

M1 is an input to the synchronization unit. It is the signal from the microprocessor that determines the mode of operation. When high, it enables counting for the video pulse mode.

The attenuators are in the receive path and are controlled from the front panel because the microprocessor controller was not implemented for the field trial.

Power Consumption:

Consider the complexity of TTL hardware - nothing much can be done here. However, using CMOS technology for this part of the system would reduce power consumption by at least 50%. This technology was not available in complete form at the time when the units were originally designed.

Operation:

No comments.

Micro Systems Engineering
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RECEIVED
NOV 25 1985

November 25, 1985

Dr. James Rossiter
Canpolar Consultants Ltd.
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Toronto, Ontario M5N 1A4

Dear Jamie,

The copy of MPB's response to the interim report arrived on Friday. I regret having aroused such apparent ill feeling by my remarks on the design, but with minor exceptions I stand by them. It seemed appropriate to make some response to the MPB response, and that is the purpose of this letter.

It appears that MPB's objections to the "tone" of the interim report stem partly from insufficient editing of my notes, which include a number of comments on circuit features which really have no significant effect on performance. The comment regarding the voltage level at which the fast ramp starts and the one concerning component drift are in this category.

The analysis given in MPB's letter of the effect of C39 on fast ramp linearity is incorrect, but the effect is nevertheless not large. The ramp will depart from a straight line drawn between the end points of the ramp by no more than .023%.

The D/A used as a slow ramp generator admittedly locates each sample within .05% of its desired position. My comment was that the D/A specification permits one pulse to be late by .05% and the next to be early by the same amount; in other words, the spacing between two consecutive pulses may be as little as .5ns, or as great as 1.5ns. This is not a purely hypothetical situation; it will happen at some points on the slow ramp (at major transitions of the D/A, e.g. from 0111111110 to 1000000000). I am not absolutely certain after only a few minutes of considering the problem that a pair of current sources generating both ramps is the best answer, but it is certainly not a silly idea. It is not a difficult thing to control the ratio of the two currents to the desired degree of accuracy, and that is all that is required here. Also, if the the circuit is laid out so that the two capacitors are grounded to a common point, differential-mode noise should be very low.

Lowpass filtering of the slow ramp by C42 causes a maximum departure from linearity of .34%, measured with reference to a straight line drawn from the ramp level at 180us to the ramp level at 2.048ms. This error occurs about 400us from the start of the ramp. Probably this is not serious.

Regarding track/hold performance, the 1V droop referred to was my estimate of the value we observed during our visit. Maybe the T/H had failed when we observed it (though Rene seemed to think it was normal) or maybe (since Rene was managing the scope) we were not observing what I thought we were. If we were in fact looking at the T/H output, droop was certainly much worse than 6.5%. I regret that we did not record any performance figures, but time was limited. I agree that a moderate degree of droop (6.5%) wouldn't matter.

Regarding the power supply, whether the 5V regulators are supplied from unregulated input or from 15V is perhaps a minor point. Even having the voltage adjustments one-sided (so that the output can be adjusted above the regulator voltage, but not below), might be acceptable for a prototype if one is willing to select regulator IC's. Such a scheme does have a negative effect on manufacturability, however.

Sincerely,

Eric Vanneson

Eric Vannerson, P.Eng.

APPENDIX B

Notes on the software design for the computer controller, October 1985

Notes on the software design for the MPB ice-thickness radar
October 21, 1985

General comments

Various combinations of modules have been linked together to produce different versions of the program. One version, undated but probably most recent based on the tint of the paper, includes a module called AVRG (it averages traces) for which we have no listing. The March 8 version (year unknown) includes this module too. The version labeled "ROM system 4 Nov" includes a module called CONT (Continuous control diagnostics), for which we have no listing; this may have been used strictly for debugging.

In general, the program seems to have a reasonable structure and is about as well documented as assembler can be. A structure chart would be helpful, showing the modules at various levels and their interrelationships.

If the project were being started today, I would certainly recommend that most of the code be written in a high-level language, e.g. Modula-2. The development tools required to program the 8088 in an HLL are readily available (though they may not have been when the work was actually done), and this approach would have saved a substantial amount of effort. If large additions are to be made to the current program, it would be worthwhile to consider a different language even now.

List of modules

The following is a list of the existing modules and their functions, more or less copied from the module headers in the listings:

INIT -- Initializes the processor, display system, interrupts, and direct memory access (DMA) controller.

CU -- Subroutines to handle the keyboard and display.

UTY -- A collection of utility subroutines.

FUNC -- Prompts the user to enter a number, which is returned to the calling module.

INT -- Initializes the interrupt system and handles illegal interrupts.

ANOP -- Subroutines for driving the analog I/O cards.

RADAR -- Procedures to control the radar interface: set the sync unit for mode and delay, trigger the radar, initialize the DMA controller, set the attenuators and phase shifters.

DIAG -- Prompts the user to specify a diagnostic program (by number), then calls that program.

PLOT -- Outputs data from memory to an X-Y plotter.

MODE -- Gets mode and delay values from the user and outputs them to the sync unit.

SCOPE -- Calls functions from CRT; used for diagnostics, apparently.

CRT -- Displays data from memory on an oscilloscope (X and Y outputs are provided).

RUN -- Controls the continuously running functions. Runs the system in any of 5 modes, as follows:

Trigger radar and place all data in Buffer 0.

Trigger radar and place the data in Buffers 0-15.

Trigger radar, place the data in Buffer 0, then display it on the CRT.

Trigger radar, place the data in Buffers 0-15, then compute the average, place it in Buffer 0, and display it.

As above, but display the individual samples following display of the average.

SET -- Sets up the delay counters, phase shifters, and attenuators.

AVRG --

DFLT -- Sets the mode and delay outputs to default values, and the phase shifter outputs to values obtained from channels 0,4,5,6,7 of the TTL input card (I don't know where these settings come from originally).

E. Vanderson.

APPENDIX C

Notes on MPB documentation, October 1985

1073 T.

Micro Systems Engineering
43 Nantucket Blvd., Scarborough, Ontario M1P 2N5. (416) 759-4055

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OCT 10 1985

October 7, 1985

Dr. James Rossiter
Canpolar Consultants Limited
421 Eglinton Ave. West, Suite 4
Toronto, Ontario M5N 1A4

Dear Jamie,

Attached are some notes on the differences between the older and new documents describing the MPB ice-thickness radar hardware.

Sincerely,

Eric Vannerson

Eric Vannerson, P.Eng.

Discrepancies between the latest documentation and the June 1984 version

Amplitude-modulated pulse:

The older document describes how this pulse was generated, but the description is not clear to me. The centre frequency was given as 100MHz; as S. Tam mentioned during our visit, it was changed recently to 90MHz.

Impulse radar detection:

Figure 4 of the 1984 report shows a square-law detector for the impulse radar signal. In the current hardware there is none; the sampler operates directly on the RF.

Packaging:

The package described in the 1984 report seems to be the new cabinet, in which no hardware has actually been installed.

Ramp generators:

When the 1984 report was written, MPB had apparently not decided between the two basic approaches to the problem discussed in the report. The decision was to be made on the basis of temperature tests, although the report seems to lean toward the "dual-slope" approach; as we know, the eventual choice was made in favour of the single-slope scheme.

Sampler:

The hardware described in June 1984 used a commercial video track/hold, rather than the later custom-built one.

Synthetic pulse:

The transmitter in the 1984 system had for each frequency a bandpass filter, phase shifter, and attenuator. The receiver had a filter bank and individual attenuators, too; these seem to be lacking in the current version.

Time base:

The time base oscillator in the present hardware runs at 30MHz; in the previous version it ran at 12.5MHz.

Notes on the differences between the SPR as described in the 1978 report and the current version

October 21, 1985

In general, the 1978 documentation is fairly hard to follow. Much of it is scratched out in my copy of the report, apparently replaced with more recent versions. I don't have a more recent version of anything except the frequency synthesizer and a block diagram of the transmitter.

Detector

The current impulse radar signal processor doesn't have anything I would call a "detector circuit", as shown on p. 62 of the 1978 report. Perhaps this is a part of the amplitude-modulated pulse scheme.

Filters

The bandpass filter bank was still shown on the receiver drawing included with the 1984 report. We have no later drawing.

Frequency syntheses

The circuitry for generating the 5 frequencies seems to have remained stable since 1978.

Impulse radar

The "impulse" radar referred to on p. 63 of the 1978 report is in fact a cw signal multiplied by a 50ns pulse.

APPENDIX D

Notes on synthetic pulse radar principle by E. Vannerson, April 1987

A.

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43 Nantucket Blvd., Scarborough, Ontario M1P 2N5. (416) 759-4055

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APR 2 - 1987

April 2, 1987

Dr. James Rossiter
Canpolar Consultants Ltd.
421 Eglinton Ave. W.
Suite 4
Toronto, Ontario M5N 1A4

Dear Jamie,

Enclosed are my report on the MPB radar bench tests and an invoice. I don't know whether you plan to submit the report as is, or merge it in your own report. In any case, I don't think there is anything in it which will prove unpalatable to MPB.

Since you checked the adjustability of amplitude and phase while Sebastian was giving me a tour of the plant, I may have misinterpreted the notes on these tests. You should probably have a good look at the corresponding part of the report.

There were some comments which I thought worth making, but which don't seem to belong in the report. First, a few regarding the redesign of the transmitter. It seems a good thing to generate the transmitted pulses in the time domain directly rather than synthesize them from sinusoids, for the sake of simplicity and economy. Of course, this approach does not inherently provide a capability for frequency equalization to compensate for antenna response. Without some form of equalization, it may not be possible to make the best use of available transmitter power and receiver sensitivity. If fixed equalization is OK, i.e. if the antenna response is known in advance, then it seems to me that a passive equalization network would provide a simpler solution to this problem than independent adjustment of several harmonics.

A separate issue is the drastic change in the nature of the transmitted signal which has taken place. Whereas the original design gave burst of six pulses approximately 7ns wide repeated at 30MHz, the new design generates only a single pulse. The original pulse shape concentrated the transmitted energy where the receiver is looking for it, i.e. around 30, 60, 90, 120, and 150MHz, as shown in the attached graph. The spectrum of the new pulse of course drops fairly smoothly from dc to the first null at about 150MHz, so most of the transmitted energy (say 5/6 of it) is wasted. Equivalent system performance would seemingly require about six times more peak power. I assume that the signal design has been compromised because the train of six pulses is difficult to generate at high power; the avalanche circuit MPB is using now, for example, takes a long time to recover between pulses.

I have thought some more about the dynamic range issue. It is obvious that high gain compromises maximum input level, and that very low gain is no good either. In order to decide on the appropriate gain, one needs to have a figure for minimum acceptable RF output, possibly based on the equivalent input noise of the sampler. There is no point in increasing the gain beyond that required to raise RF input noise to this level; signals smaller than the RF input noise will still be undetectable, but overload will occur for smaller inputs. I haven't a good feel for the signal level the sampler should see. If you have, maybe you can conclude that MPB has too much gain.

Regarding the advantages of synthetic pulse radar, I am not sure what they are either. The highest frequencies sampled are around 150MHz, but the system bandwidth is still only 25MHz. Without the bandpass filters in the receiver, the noise bandwidth would be about six times greater, so transmitter power would need to be increased correspondingly for the same S/N ratio. Does sampling the spectrum like this somehow yield performance that is almost as good as the brute force approach?

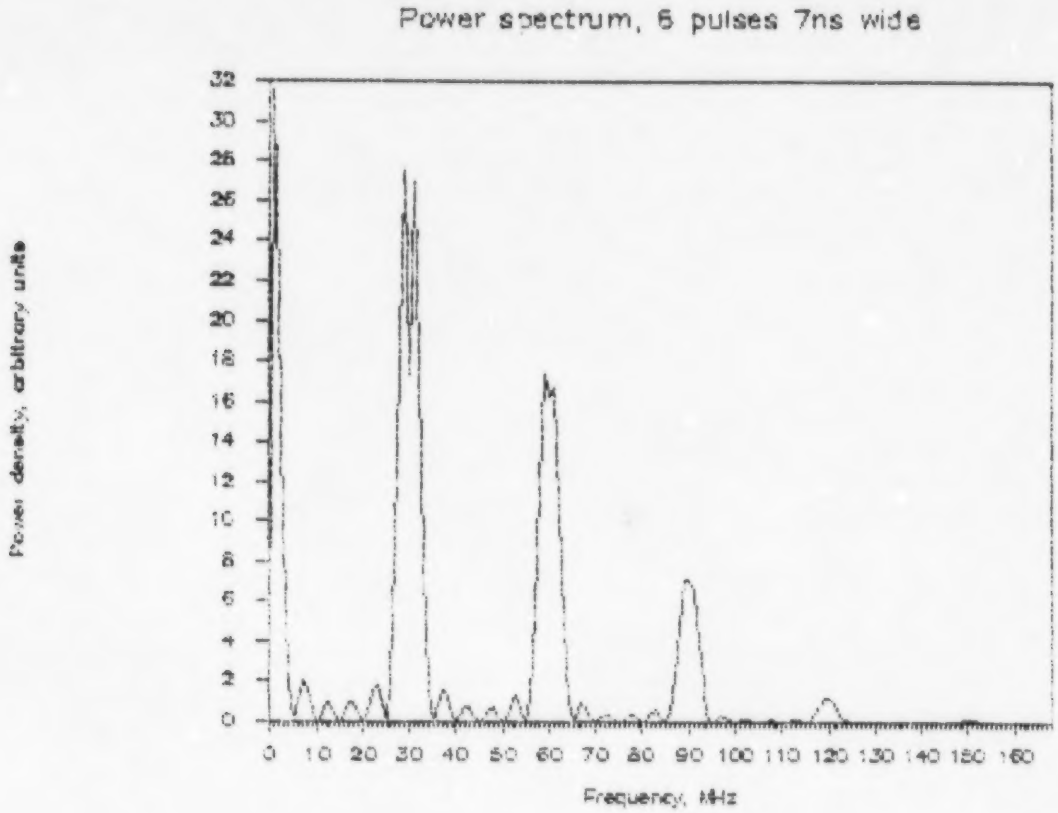
Another question I have is whether the sampling rate might not be higher than necessary. As I recall, the effective sampling rate is 1GHz (1ns additional delay on each sample). Since there is very little signal power above 135MHz, it's hard to see why the sampling rate could not be cut by about half. Also, since most of the signal spectrum is empty, is there not some way to reduce the sampling rate further? For example, could one heterodyne the passbands downward in frequency so that they are almost contiguous, then sample at, say, 100MHz? Maybe this is fallacious, but if not then one could presumably cover the ranges of interest with fewer pulses, and as a consequence either reduce the error due to horizontal motion, or improve productivity by flying faster.

Lots of things to think about.

Regards,

Eric Vanneman

Eric Vanneman



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